Ocean Surface Turbulence and Air Entrainment in the "Fluxes, Airs-Sea Interaction and Remote Sensing" (FAIRS) Experiment

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LONG TERM GOAL

Our goal is to develop improved understanding of the link between wave breaking, bubble injection, temperature fine structure and turbulence, and its contribution to remote sensing signatures relevant to air-sea flux measurement.

SCIENTIFIC OBJECTIVES

The FAIRS project will bring together an extensive set of remote sensing and atmospheric measurement. Our objective is to provide the near surface ocean measurements that will contribute to the interpretation of remotely sensed signals, including infra red imaging and radar scattering. The objective is to acquire measurements of the small scale physical processes associated with wave breaking and upper ocean turbulence, as near as possible to the area being sensed remotely.

APPROACH

Our approach is to design and build a sensor array and to deploy it from R/P FLIP during the FAIRS experiment. Our observational approach includes both *in situ* measurement and acoustic remote sensing. The wave structure and near surface bubble distribution will be measured with an array of eight narrow beam Doppler sonars mounted on the vessel's hull, together with sensors deployed on a floating package connected to FLIP. The floating package includes an array of acoustic resonators for measuring bubble size distributions as a function of depth and time, coherent Doppler sonars for direct measurement of turbulent velocity fluctuations and an array of temperature sensors for detecting the thermal signatures of wave breaking and the link between Langmuir circulation and the surface thermal structure. Supporting data will be obtained with CTD profiles and a combination of subsurface and downwards pointing video.

WORK COMPLETED

Although the FAIRS field study is just beginning as this summary is being prepared, we can report on the completion of analysis of data acquired as part of our continuing investigation of wave breaking, turbulence and related phenomena. A collaboration with M Banner is leading to new results on the link between the surface wave environment and wave breaking. Earlier measurements of wave breaking acquired with a hydrophone array have been re-examined in the light of recent research on the intensity of wave breaking events and their celerity. The primary signal for inferring intensity in this case is the acoustically radiated signal. A further study with M Banner and J Gemmrich examined the probability of breaking in terms of measured nonlinearity of the wave field. This analysis has been carried out not only to look at overall probabilities, but also breaking probability in different frequency bands. Analysis of bubble size distributions at defined locations within a measured 2-D field of upper ocean bubble clouds has provided a starting point for explaining bubble size in terms of the effects of injection by wave breaking events, turbulent diffusion and advection by Langmuir circulation. The results are being analyzed collaboratively with S Vagle and M Li. Bubble size distributions at the point of injection are being analyzed in terms of a fluid dynamical model developed in collaboration with C Garrett and M Li.

RESULTS

In preparation for the FAIRS cruise, a new Doppler sonar board has been implemented with increased flexibility, sensitivity and dynamic range. The resonator electronics have been revised to include recent improvements. At the time of writing this report, all systems are operational on R/P FLIP. In the analysis of prior work we have determined that the probability of wave breaking can be described as a linear function of wave saturation in a given frequency band. The onset of wave breaking appears to be described by a constant wave saturation threshold.

Figure 1a shows the breaking probability measured within the wave spectral peak region and shows that the probability increases with increasing wave saturation. Three data sets are included from different storms, describing a wide range of wave conditions; they all collapse on to a linear relation with a saturation threshold of $\sigma \sim 0.015$ defining the onset of breaking. In Figure 1b similar dependence is seen for the high frequency band width (center frequency of 2.48 times the spectral peak frequency). All of the analyzed frequency bands exhibit a common threshold dependence. This suggests that wave breaking can be inferred for all wave bands using the measured saturation threshold relationship.

IMPACT/APPLICATION

The analysis of wave breaking, bubble distributions and temperature structure, analysis of which is summarized above, provides a basis for improved models of upper ocean physics, especially as it relates to heat and momentum transport and the bubble contribution to air-sea gas exchanges. The identification of a common saturation threshold for wave breaking has application to the implementation of improved wave models and the representation of energy dissipation.

Development of improved instrumentation for the FAIRS experiment will allow us to acquire measurements of turbulence dissipation close to the ocean surface and to use these measurements to determine the link to remotely sensed signatures.

TRANSITIONS

The FAIRS project represents our contribution to the collaborative study of upper ocean processes and their remotely sensed signature.

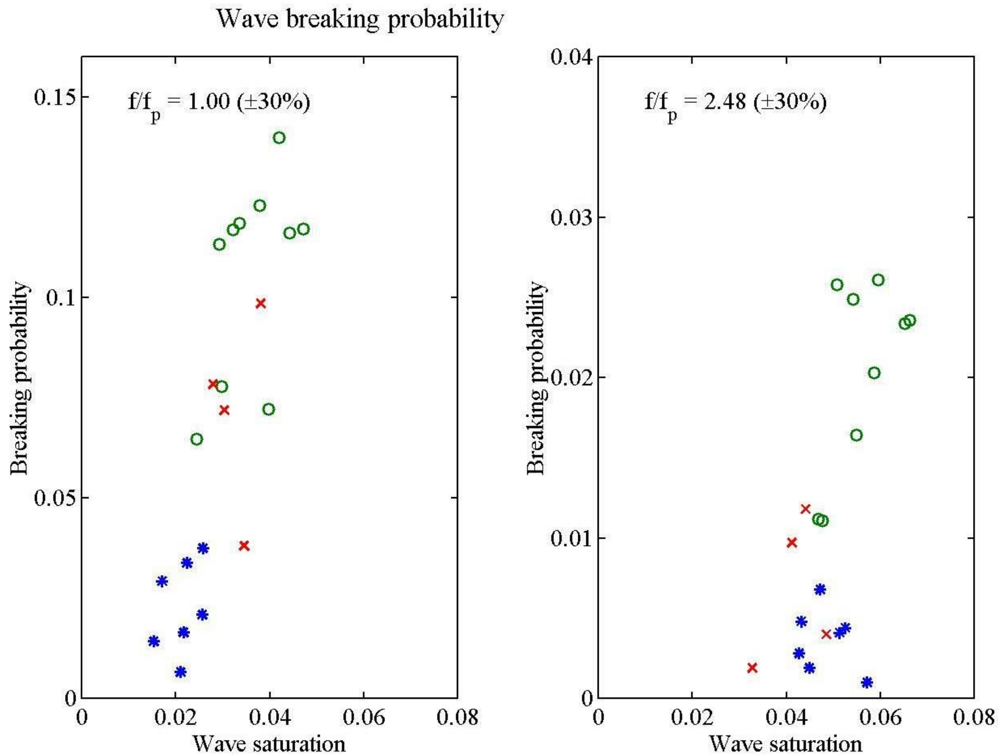

Figure 1a **Figure 1b**

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